

Solar Measuring Device

MacSolar

Manual

Contents:

1. Introduction	2
2. Operation	3
2.1 Getting started with the MacSolar	3
2.2 The functions and their physical meaning	4
2.3 The modes of the MacSolar and their physical and practical meaning	5
2.4 The special functions	8
2.5 Other functions	9
2.6 Power management	10
3. Measuring	10
3.1 Direct measurements	11
3.2 Maximum value measurements	11
3.3 Average value measurements	12
3.4 Data logging measurements	12
4. Technical Data	14

1. Introduction

The MacSolar solar-radiation measuring device has been developed as a useful tool especially for solar engineers, architects and hobby users. The MacSolar facilitates the direct and uncomplicated measuring of the actual intensity of light: The sensor, power supply and display are integrated in a handy and compact apparatus. The user can thus obtain immediate information on the light conditions at various locations of an object. In addition, typical nominal data of a solar module such as voltage, current or power are determined by the MacSolar. The user can thus obtain immediate information about the composition and concept of a photovoltaic system.

Measurements are made by means of monocrystalline silicon solar cells which additionally takes over the energy supply of the device. The internal microprocessor provides automatic correction in order to obtain fundamental precision after calibration of each unit in a solar simulator.

Four different measurement modes can be selected:

dir - displays the current measurements

hi - displays the maximum value during a measurement period

avr - displays the calculated average values during a measurement period

sto - internally stores values in a fixed time pattern

In all modes, the values of P_{tot} (in W/m^2), P_n , U_n , I_n (in %) or T (in $^{\circ}C$) can be displayed. The data filed in internal storage can be transmitted via digital output to the serial interface of a PC.

The MacSolar has been developed for outdoor use and is equipped with a weather-proof plastic case. Its compact size enables a comfortable one-hand operation.

The standard version includes a fastening bow which can be swivelled by $\pm 90^{\circ}$. The MacSolar can simply be inserted into this holder, thus enabling long-term measurements at all kinds of locations.

Some typical applications for the MacSolar are:

- direct measurement of the actual light intensity
- comparative averaged readings at different locations
- long-term measurements with internal data logging or averaging
- simulation of a silicon solar module under real conditions

4. Technical Data

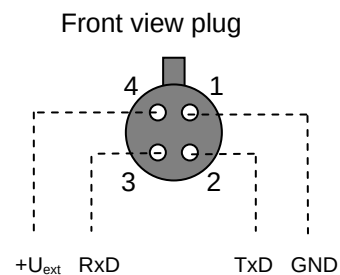
Measuring range / Resolution:	see Tab. 1
Overall accuracy P_{tot} :	$< 3\% \pm 1\text{digit}$ (50 ... 1000 W/m ² / AM1,5 / normal incidence / $T_{modul} = 0 \dots +50 \text{ }^{\circ}\text{C}$)
Overall accuracy T:	$< 3K \pm 1\text{digit}$ ($-25 \dots +75 \text{ }^{\circ}\text{C}$) $< 1\% \pm 1\text{digit}$ on request
Power consumption (sleep mode):	0,6 mW
Power consumption (active mode):	4 mW
Rated power of integrated solar panel:	180 mW *
Power supply externa:	9-12 V / 20 mA
Data storage capacity:	256 kbit
Data transmission:	seriell (RS232)
Ambiente temperature range:	$-20 \dots +50 \text{ }^{\circ}\text{C}$
Max. ambiente humidity:	95 %
Dimensions (without fastening bow):	130 x 90 x 30 mm
Weight (without fastening bow):	170g
Certification:	CE/ EN50081, EN50082, EN60068
Calibration:	according to IEC904/3 Calibration certificate on request
Warrenty:	2 years

* at standard test conditions: $P_{tot} = 1000 \text{ W/m}^2$, spectrum AM1,5, $T = 25 \text{ }^{\circ}\text{C}$

Rear jack

plug/jack: Fa. Binder, Typ 719

A powersupply to $+U_{ext}$ with 5-10 mA is occurred by means of the interface cable.



2. Operation

2.1 Getting started with the MacSolar

On its front panel, the MacSolar is equipped with a 4-digit LCD display, an LED row and 5 microtouch keys as explained in Fig. 1. Basically, pressing a key initially results in the display of the respective function for a period of 1 second. Within this period, the function can be changed by pressing the same key once more. After one second the value associated with the actual function is displayed. During measuring, the LED with the respective unit is flashing.

The MacSolar is not equipped with a „Power Off“ key. It starts to work by simply pressing the „Start/Stop“ key on the front panel. 2 minutes after the last key has been pressed, the MacSolar turns off by itself, except

- while performing a measurement in the *hi* mode: here it stays active all the time (display on).
- while performing an *avr* or *sto* measurement: here it goes idle after 2 minutes and is interrupted every 10 seconds for a short data sampling process. In this mode, the display stays off all the time

Some functions are activated by pressing the „Hold“ key and one of the four surrounding keys simultaneously. Therefore you push the respective key without let go off and after this you push the „Hold“ key.

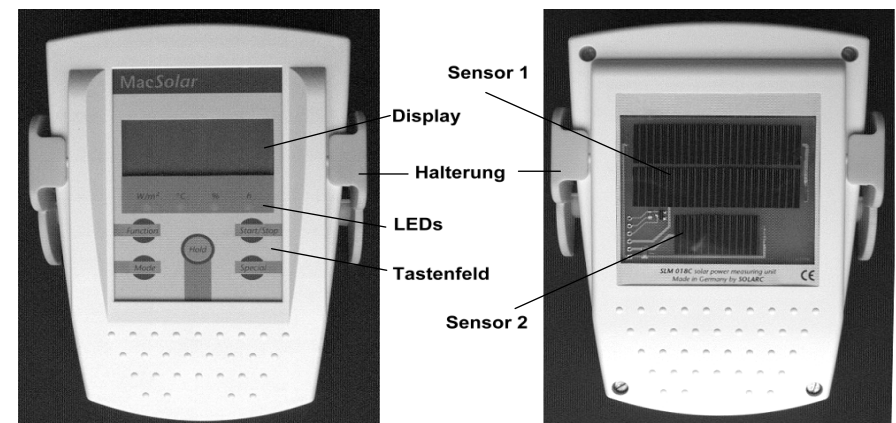


Fig. 1: Front and rear view of the MacSolar

2.2 The functions and their physical meaning

The MacSolar performs 6 different measurement readings. These are called „functions“ and are adjusted with the „Function“ key:

P_{tot} (Light intensity): Power of total light radiation per square meter. In the by far most expensive light measurement device, the pyranometer, the light spectrum does not affect the result. In the case of silicon sensors as used in the MacSolar, the device has to be calibrated to a certain light spectrum. After that every light source with a similar spectrum can be measured fairly accurately.

According to its name, the MacSolar is calibrated to the solar spectrum and thus will give exact values of P_{tot} when exposed to daylight. Calibration is carried out with a solar simulator under so-called „Standard Test Conditions“ (STC): AM1,5 spectrum, $P_{tot} = 1000 \text{ W/m}^2$ (at 25°C) which is similar to direct sunlight at noon in Middle Europe. An illustration of the AM1,5 solar spectrum and the spectra of several different light sources is shown in Fig. 2.

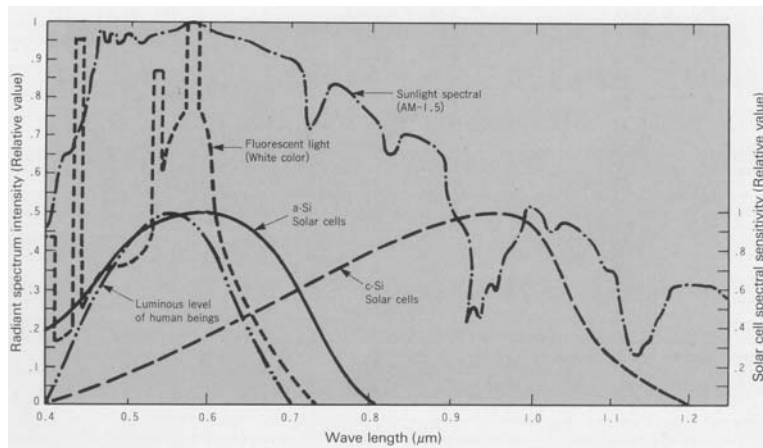


Fig. 2: Spectra of different light sources and solar cells

$^{\circ}\text{C}$ (panel temperature): Temperature as measured on the solar cell measuring unit at the back of the MacSolar and corrected due to the selected temperature coefficient t_c . The measured value corresponds to that of a solar panel at a similar position as the MacSolar in relation to the heat flow (see also ch. 2.4).

P_n (module power): Electric power in the operating point (MPP) of a silicon solar modul at a defined light intensity and module temperature. The value for P_n is displayed in % and is applicable only to mono- or polycrystalline-

The MacSolar can now internally store data for up to 20 months (time interval 1h, $tb1$) and up to 2 months (time interval 0,1h, $tb2$). The measuring should be canceled before houroverflow after 13,6 months or 9.999 hours. On conclusion of the measurement, the stored data are transmitted to a PC by means of the optional interface cable. For further details on cable and PC software, see the operating instructions of the Interface Package.

The obtained data may be used e. g. for proving the yield of an installed solar system by simultaneous data logging of its output power. The PC software SLMview, which is part of the Interface Package, enables a detailed analysis of the ASCII data. Otherwise Excel can be used to analyse the values.



Fig. 6: Measurement performance at a fixed position

stopped first. After the measurement the values of all functions determined at the point of time where the maximum value of P_{tot} occurred are stored and may be selected on the display with the „Function“ key. Note that the stored maximum values may be less exact for the temperature and the temperature dependant functions (P_n , U_n , I_n) because of the large temperature time constant of the sensor unit.

3.3 Average value measurements

Aim: Long-term determination of the average value of all current functions (P_{tot} , °C, P_n , U_n , I_n) at a fixed position.

Adjustment: Function P_{tot} , Mode *avr*

Procedure: Select the correct values for the special functions *tc*, *Si* and *tb*. Start the *avr* measurement by pressing the „Start/Stop“ and „Hold“ key simultaneously in the *avr* mode. Note that the *avr* measurement cannot be started while performing a *hi* or *sto* measurement which has to be stopped first. For a fixed position you should attach the metal bow with one or two screws at its rear side. Insert the MacSolar in the plastic holder which can be adjusted in the metal bow in a defined angle. Make a note of the time when the measurement is started.

After a defined measurement duration which can be displayed by the *hour* function the measurement is stopped in the same way as it was started. Alternatively it may be just interrupted with the „Hold“ key and continued afterwards. The measurement duration is only limited by the maximum value of the *hour* function (9999 h). The stored averaged values of all functions can now e. g. be compared to those obtained in the same time period at another position with a second MacSolar device. Note that the stored averaged value of U_n may be irrelevant since in many systems there is a lower limit for the voltage below which no current flow from the solar modules occurs.

3.4 Data logging measurements

Aim: Long-term data storage of P_{tot} and °C every 1 (0,1) hour at a fixed position.

Adjustment: Function P_{tot} , Mode *sto*

Procedure: Select the correct values for the special functions *tc*, *Si* and *tb*. Start the *sto* measurement by pressing the „Start/Stop“ and „Hold“ key simultaneously in the *sto* mode. Note that the *sto* measurement cannot be started while performing a *hi* or *avr* measurement which has to be stopped first. Install the MacSolar as described above. Mark the starting time.

modules. For a 50 W_p module, for example, the display of 50 % amounts to 25 W power. P_n is calculated from U_n and I_n due to $P_n = U_n \cdot I_n$.

U_n (solar cell voltage): Voltage at maximum power of a solar panel at a certain light intensity and panel temperature. The solar cell voltage is a logarithmic function of the light intensity P_{tot} and thus only varies to a slight extent even at large differences of P_{tot} . The value for U_n is displayed in %.

I_n (solar cell current): Current at maximum power of a solar panel at a certain light intensity and panel temperature. The value for I_n is displayed in %.

hour (measurement duration): Number of hours since a measurement has been started. Up to a value of 999.9 hours the resolution is 0.1 hours, then it switches to 1 hour until 9999 hours. A year (365 days) has 8760 hours.

The overflow of a value is displayed as „OF“. During a *avr* or *sto* measurement the maximum value of the respective function is stored (compare Tab. 1).

Tab. 1: Overview on the functions of the MacSolar

	P_{tot}	°C	P_n	U_n	I_n	<i>hour</i>
Unit	W/m ²	°C	%	%	%	h
Max/Min values	0 ... 1500	-40 ... +85	0 ... 150	0 ... 150	0 ... 150	0 ... 9999
Resolution	1	0.1	0.1	0.1	0.1	0.1 / 1

2.3 The modes of the MacSolar and their physical and practical meaning

The functions P_{tot} , °C, P_n , U_n and I_n can be displayed in 4 measurement „modes“ as also shown in Fig. 3:

dir: Actual value of each function as measured within a second. This mode is used for a quick check of the actual values at the chosen position. Very helpful is the use of the „Hold“ key that freezes the actual values of all functions when pressed once. Pressing the „Hold“ key a second time continues the measurement of the actual values. The other functions can be checked during the „Hold“ function

hi: Maximum value of P_{tot} after starting a measurement. This mode, for instance, allows the determination of the highest value of P_{tot} during a day at a defined position.

The measurement is started in the *hi* mode by pressing the „Start/Stop“ and „Hold“ key simultaneously. In the same way the measurement is

terminated. The values of all functions determined at the point of time where the maximum value of P_{tot} occurs are stored and may be selected on the display by means of the „Function“ key. They are cancelled by starting a new measurement in the *hi* mode. By means of the „Hold“ key the measurement is stopped (*hold*) and continued (*run*).

Attention: During the *hi* measurement, the device does not go into idle mode and thus has a higher power consumption which can be supplied from the built-in solar module only at adequate light conditions. Therefore it should not be used for long-term measurements.

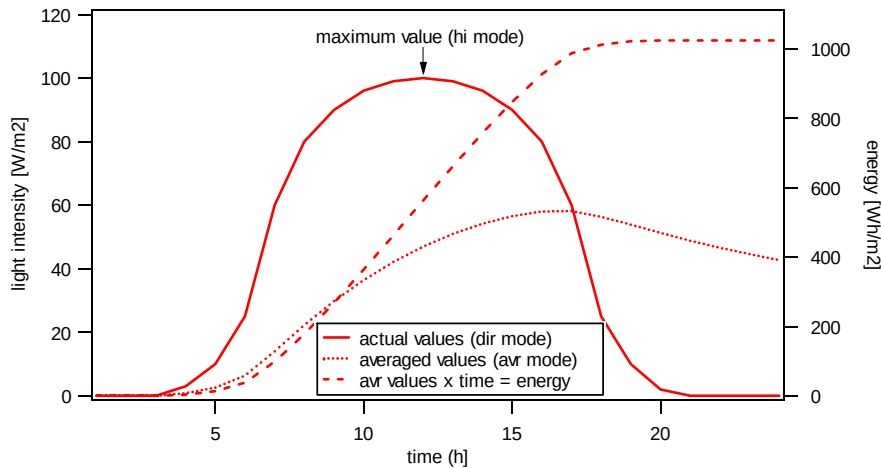


Fig. 3: Measurement intervals and modes

avr: Average value of each function after starting an *avr* measurement. The average mode is very useful to determine a long-term average power or energy yield at a certain position. For the latter the obtained averaged value of P_{tot} is simply multiplied with the *hour* value. With several MacSolar units at different positions, running at the same time in the *avr* mode, the position with the highest energy yield is determined very accurately. Unlike to so-called solar simulation software programs, this measurement is performed in real conditions including all parameters as temperature, humidity, wind, shade etc.

The measurement is started in the *avr* mode by pressing the „Start/Stop“ and „Hold“ key simultaneously. In the same way the measurement is terminated. Then the respective average values of all functions are stored and may be selected on the display by means of the „Function“ key. They are cancelled by starting a new measurement in the *avr* mode. By means of the „Hold“ key the measurement may be stopped (*hold*) and continued (*run*).

3.1 Direct measurements

Aim: Determination of all momentary functions (P_{tot} , $^{\circ}C$, P_n , U_n , I_n) at a certain position.

Adjustment: any function, Mode *dir*

Procedure: Orientate the measuring sensor towards the correct location by positioning the MacSolar accordingly in the holder or in your hand. In order to correctly determine P_n , U_n , I_n , the temperature should have reached a constant value. You can either read the measured value directly on the display, or press the „Hold“ key for a short time. Then select the required function by pressing the „Function“ key and read the stored measurement. Please take into account that the calculation of the values of P_n , U_n and I_n is affected by the parameters set by means of the special functions Si and t_c (see Para. 2.4).



Fig. 5: Measurement performance of actual values with the MacSolar

3.2 Maximum value measurements

aim: Determination of the maximum value of all current functions (P_{tot} , $^{\circ}C$, P_n , U_n , I_n) at a fixed position or determination of the respective position.

Adjustment: Function P_{tot} , Mode *hi*

Procedure: Select the correct values for the special functions t_c , Si and t_b . Start the *hi* measurement by pressing the „Start/Stop“ and „Hold“ key simultaneously in the *hi* mode. Note that the *hi* measurement cannot be started while performing an *avr* or *sto* measurement which has to be

Serial-No.: If you need to know the serial number of your MacSolar device you can get it on the display by pressing the keys „Mode“ + „Hold“ for 3 seconds. Afterwards a display-check (all segments on) and the 8-digit serial number appears consequently.

2.6 Power management

Power consumption of the MacSolar during idle operation (i. e. during a measurement in the *avr* or *sto* mode) is very low: At moderate temperature, the device can be powered by the internal battery for more than 3 months without any light. After that period, the MacSolar will switch off completely in order to prevent deep discharge of the battery. Exposing the solar cell for at least 2 hours to a bright lamp or to sunlight will reactivate the internal battery.

Switching off will never occur during an outdoor measurement since the measuring subject is light which even at low intensities powers the electronic circuit of the MacSolar: While performing an *avr* or *sto* measurement the solar cell of the MacSolar should be supplied with a daily light energy of at least 250 Wh/m². Such a value is obtained in the open during an average winter day in Northern Germany. At lower light intensities, power supply of the MacSolar is supported by the internal battery for up to 3 months.

After turning off (without any running measurement) the MacSolar can be powered by the internal battery for more than 15 months without any light. Reactivation is performed as described above. For permanent service it is useful to keep the device upside down at a bright place.

The MacSolar is additionally supplied with power by the rear jack. Therefore you need a 9-12V / 20mA powersupply. A discharged battery is charged in 48 hours. Overcharging is not possible.

3. Measuring

There is a large variety of measurements which can be performed by means of the MacSolar. This chapter presents only a selection of them as typical examples.

During an *avr* measurement, the maximum values measured are also stored (see *hi* Mode) and can be displayed in *hi* Mode without this affecting the measurement in progress. The same applies to the current values (*dir* Mode).

sto: Long-term data logging with storage intervals of 0,1 or 1 h. In this mode, only the values of P_{tot} and the measured module temperature (not corrected due to the value of t_c) are stored. The values are measured every 10 seconds and averaged between the storage intervals (see Fig 4). The last value stored in the internal memory is displayed. The *sto* mode is useful only in connection with the Interface Package, by means of which the measured data can be transmitted to a PC. It may be used e. g. for testing the efficiency as well as the possible yield of solar systems over a period of up to approx 20 months. The internal memory is able to store 15.000 values. After 9.999 hours (13,6 months) an overflow occurs when it stored every hour. In this case the measuring should be canceled before

The measurement is started in the *sto* mode by pressing the „Start/Stop“ and „Hold“ key simultaneously. In the same way the measurement is terminated.

During the *avr* measurement, the maximum and average value of each function is calculated additionally and can be displayed by changing to the *hi* or *avr* mode while the current measurement is continued. In addition, the actual values can be displayed by changing to the *dir* mode.

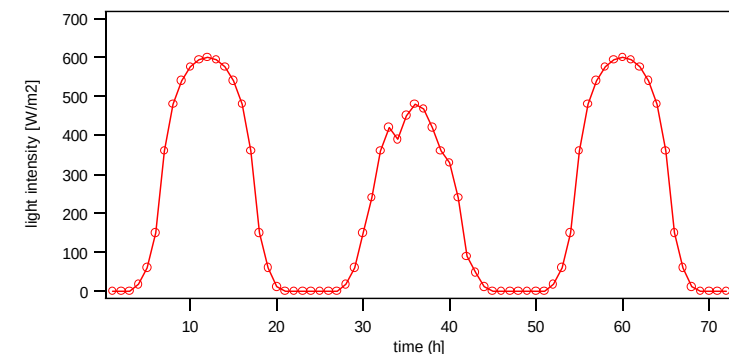


Fig. 4: Long-term data logging (*sto*, storage intervals of 1 h)

Tab. 2: Overview on the modes of the MacSolar

	<i>dir</i>	<i>hi</i>	<i>avr</i>	<i>sto</i>
Measurement intervals	1 sec.	1 sec.	10 sec.	10 sec.
Start/Stop key function	off	Start/Stop only in <i>hi</i> mode	Start/Stop only in <i>avr</i> mode	Start/Stop only in <i>sto</i> mode
Hold key function	<i>hold</i> = 1 x <i>run</i> = 1 x	<i>hold</i> = 2 x <i>run</i> = 2 x	<i>hold</i> = 2 x <i>run</i> = 2 x	<i>hold</i> = 2 x <i>run</i> = 2 x
display marker	off	Decimal point	Colon	Decimalpoint & Colon

2.4 The special functions

By means of the "Special" key, several sophisticated operations can be performed. A change of the values within a special function requires pressing the „Special“ and „Hold“ key simultaneously for 3 seconds. The functions *tc*, *Si* und *tb* cannot be changed while performing a measurement (*hi*, *avr*, *sto*).

tc: Change of the temperature coefficient *tc* which determines the dependance of the solar cell parameters P_n , U_n and I_n from the temperature. An exact simulation of solar panels with the MacSolar hence requires a correct adjustment of *tc* due to their installation conditions. Here

tc 1 relates to a panel installed in the open

tc 2 relates to a panel installed a few centimeters away from a roof or wall

tc 3 relates to a panel with isolated back (e. g. integrated into a roof).

Default value: **tc 2**

Si: Change of the characteristic function which describes the dependance of the solar cell voltage U_n of the light intensity P_{tot} :

Si 1 for a typical high-efficiency monocrystalline solar panel that responds to lower light intensities with only a slight decrease of efficiency

Si 2 for a solar panel that responds to lower light intensities with a medium degree of efficiency

Si 3 for a solar panel that responds to lower light intensities with a high decrease of efficiency

Default value: **Si 2**

CAL(CAL.u): Activation of the software calibration mode for the light sensors on the rear panel. In this mode the user may calibrate the MacSolar with his own calibration system which is e. g. a solar simulator or the sun itself in a defined condition. Furthermore, calibration to a different light spectrum is possible as well if its predominant part is not below a wavelength of 1100 nm.

The calibration procedure is initiated by pressing the „Special“ and „Hold“ key simultaneously for 3 seconds. After that the display counts down from CAL9 to CAL0 in 1 second steps. At CAL0, the sensor of the MacSolar must be in a position corresponding to a light intensity of $P_{tot} = 1000 \text{ W/m}^2$. A new set of calibration values will be generated by the software of the MacSolar (display: CAL.u) and remains in the internal storage even in a case of a total energy breakdown of the internal battery. If the light intensity is lower than 200 W/m^2 during calibration the manufacturer's default calibration values will be used (display: CAL). So the user can return to the default calibration values by simply keeping the MacSolar with its back side on the table during a calibration process.

OUT: Data transmission to PC. This function allows the complete set of data stored by the MacSolar to be transmitted to the PC via the digital output at the rear. The Interface Package, which is available as an accessory, is required for this. The function OUT is started by pressing simultaneously the „Special“ and „Hold“ key for 3 seconds. Transmission is displayed by a blinking decimal point.

Normally, data transmission is initiated from the PC, in which case the OUT function is not required.

tb: Change of the storage intervals 1h (*tb1*) and 0,1 h (*tb2*) in the *sto* mode

Default value: **tb1**

2.5 Other functions

Error-code message: In case of trouble in the electronic circuit or the microcomputer of the MacSolar an error-code (as e. g. *Er12*) is displayed in short intervals. If the error has vanished the error-code display can be removed by pressing of the "Special" key. Please note the error-code anyway and inform your merchandiser or SOLARC.